

## Abstract

We have measured the energy sharing among three massive coulomb-interacting particles for a unique end-state configuration. The fragments are formed from colliding 4 keV  $D_3^+$  onto He, dissociating into the Coulomb interacting channel  $D^+ + D^+ + D^-$ . In the laboratory frame, we resolve the momenta of all three particles in triple coincidence leading to a measurement of the center-of-mass (cm) energy partitioning as well as the correlation angles. A distillation of all the three body events is shown as a distribution on a Dalitz plot. In this measurement, we analyzed the possible final states where the  $D^-$  and  $D^+$  are in close proximity where simulations show the possibility of the  $D^-$  and  $D^+$  becoming bound. Final states of a bound  $D^- + D^+$  forming planetary atoms exhibit a particular signature on the Dalitz plot. Possible mass dependent effects will be discussed.

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## Motivation

Preliminary results from numerical simulations of the three body coulomb interacting system  $H^+ + H^+ + H$  shows the possibility of forming "planetary atoms", where a  $H^+$  and a  $H^-$  becoming weakly bound.<sup>1</sup>

These planetary atoms are characterized by

- Fragments interacting through coulomb potential
- Ion separation around 6 – 10 nm
- System can be modeled through classical interactions
- Formation is dependant on the total kinetic energy and total angular momentum of three body system

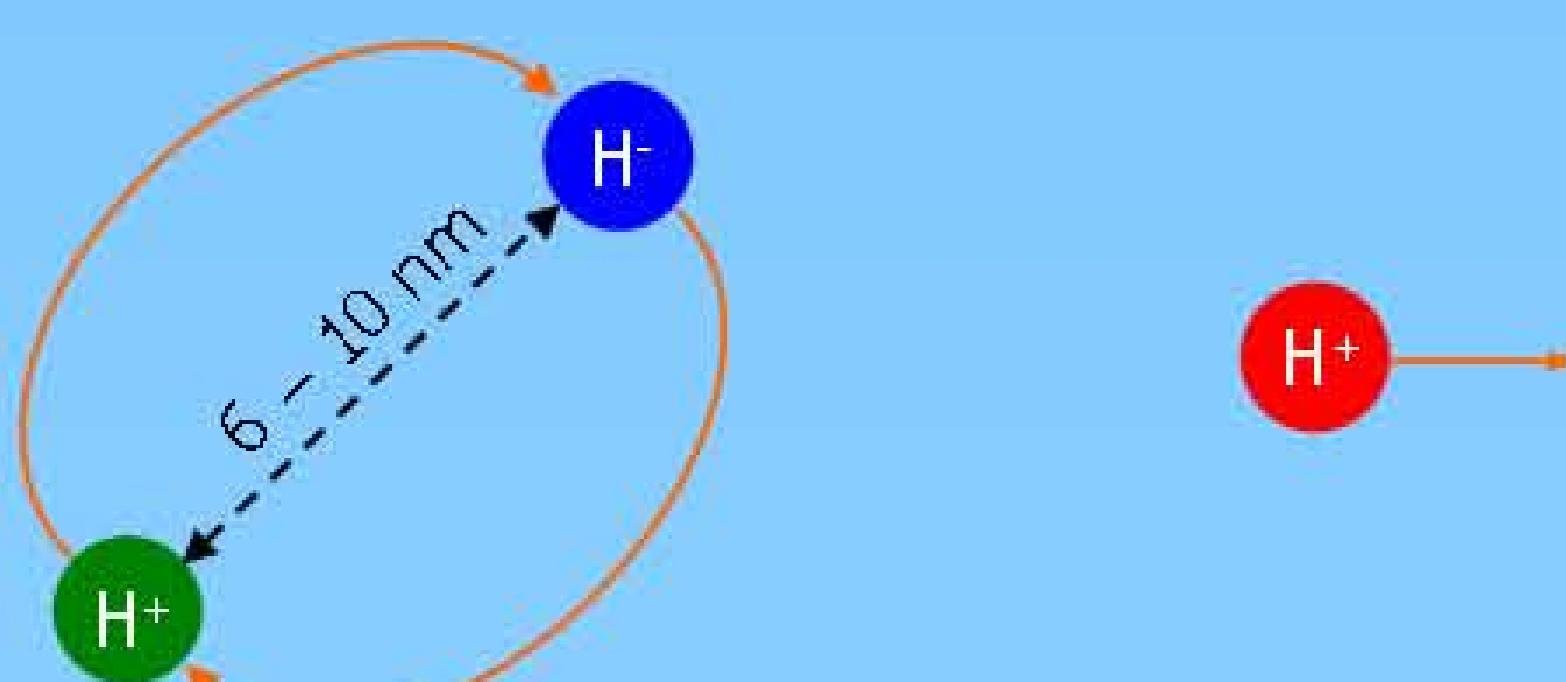


Figure 1. Cartoon of planetary atoms with respect to the cm frame of the  $H_2^+$ .

These systems are a unique opportunity to study weakly bound, highly excited hydrogen-like molecules in the classical regime.

To investigate the mass dependence on the formation of these planetary atoms, we use easily accessible three body coulomb system,  $D^+ + D^+ + D^-$ .

## Experiment

We collide 4 keV  $D_3^+$  onto He which then dissociates to a system of Coulomb interacting particles  $D^+, D^+$  and  $D^-$ .

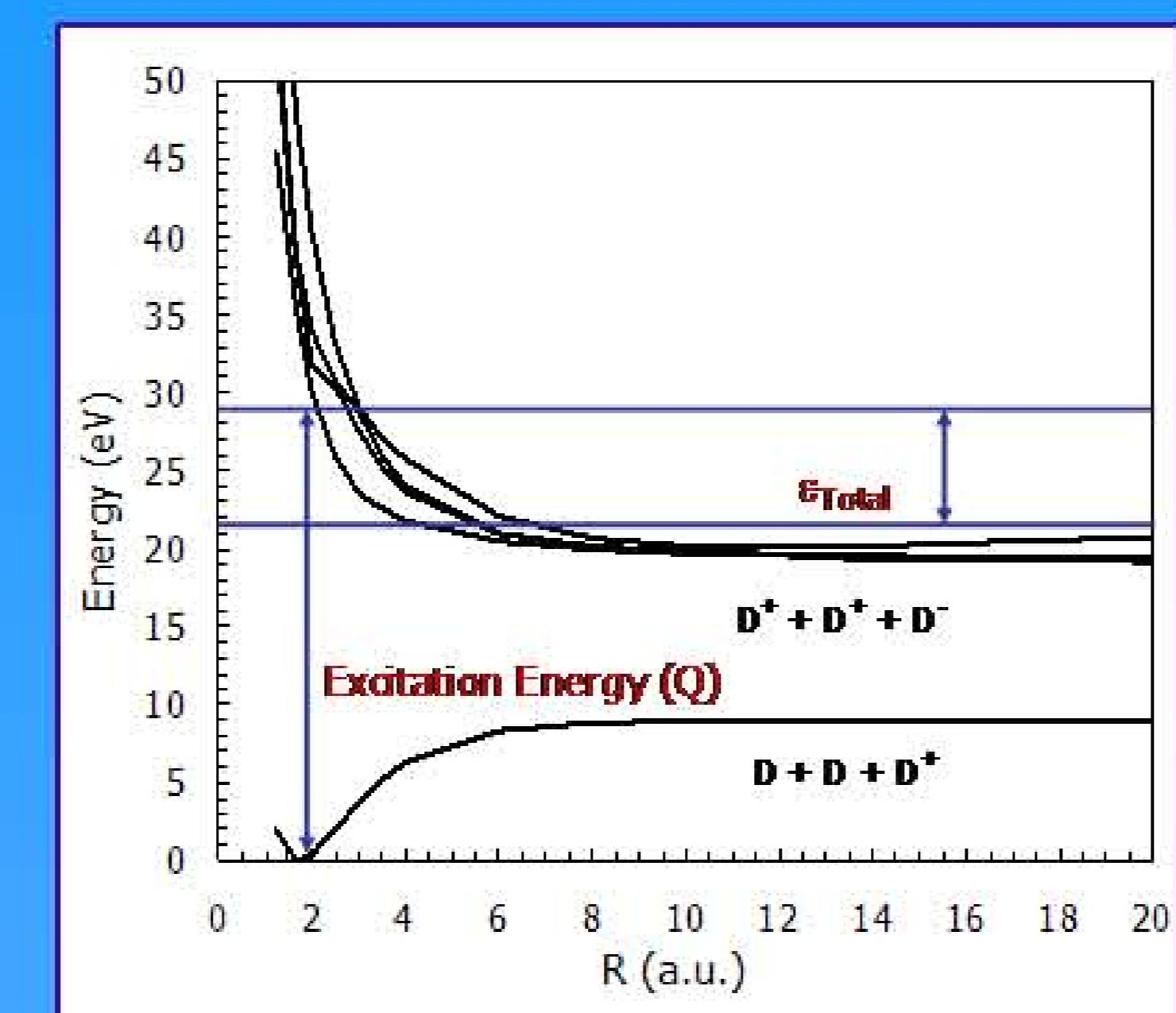


Figure 2. Potential Curves of  $D_3^+$  with the measured excitation energy,  $Q$  and the measured total cm energy,  $\epsilon_{Total}$ .

In the laboratory frame each fragment's energy and scattering angle is measured in triple coincidence with a parallel plate analyzer utilizing PSD's. A transformation to the cm frame yields the cm energies ( $\epsilon_{Fast D^+}, \epsilon_{Slow D^+}, \epsilon_{D^-}$ ) and cm scattering angles ( $\phi_{Fast D^+}, \phi_{Slow D^+}, \phi_{D^-}$ ) on an event-by-event basis, as well as the displacement from the beam axis,  $a$ . The correlation angle  $\phi_{CA}$  is found by  $\phi_{Fast D^+} - \phi_{Slow D^+}$ .

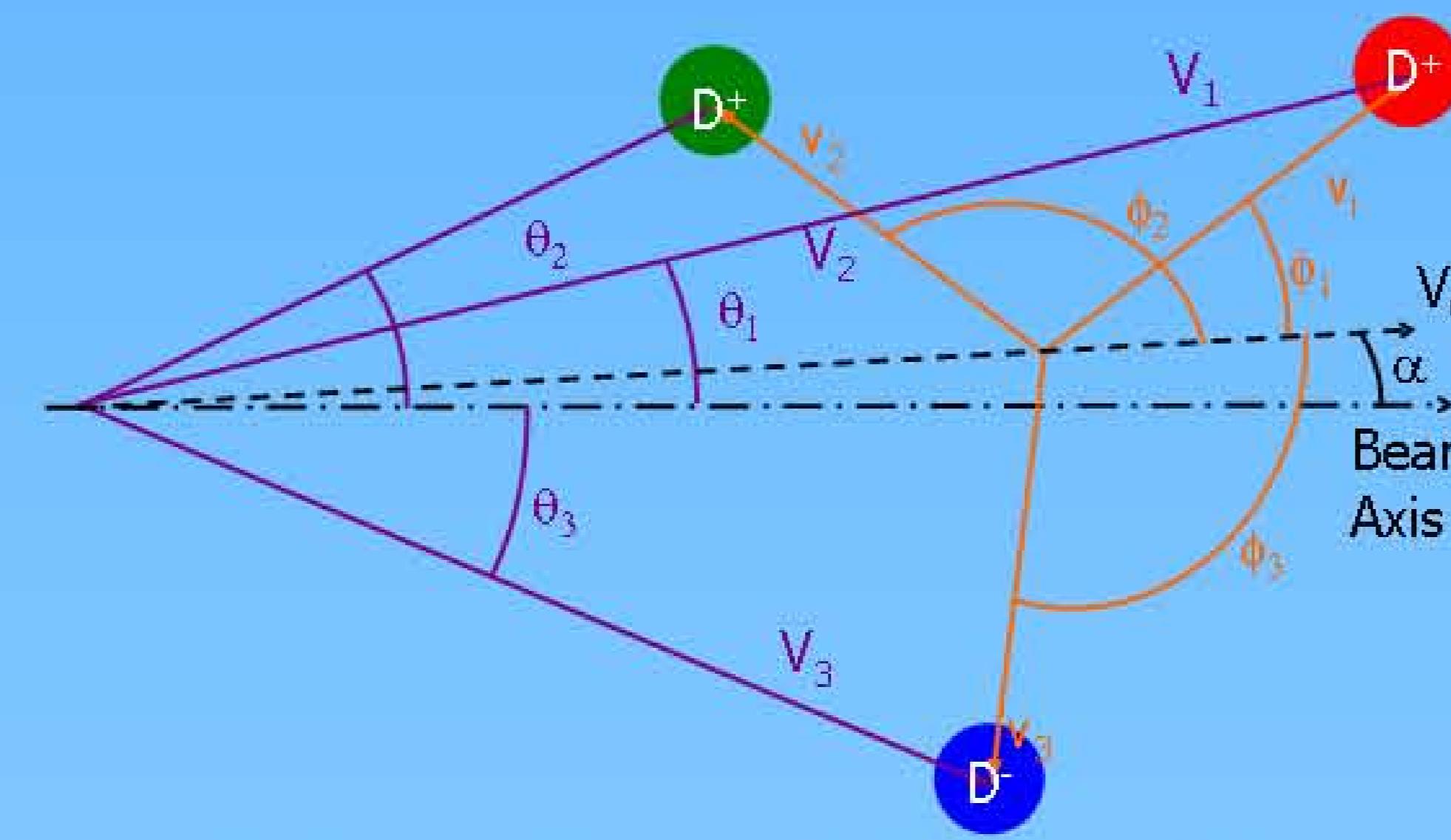


Figure 3. Newton Diagram for breakup of  $D_3^+$ .

## Results

After 6 weeks of collecting, we have 5913 events.

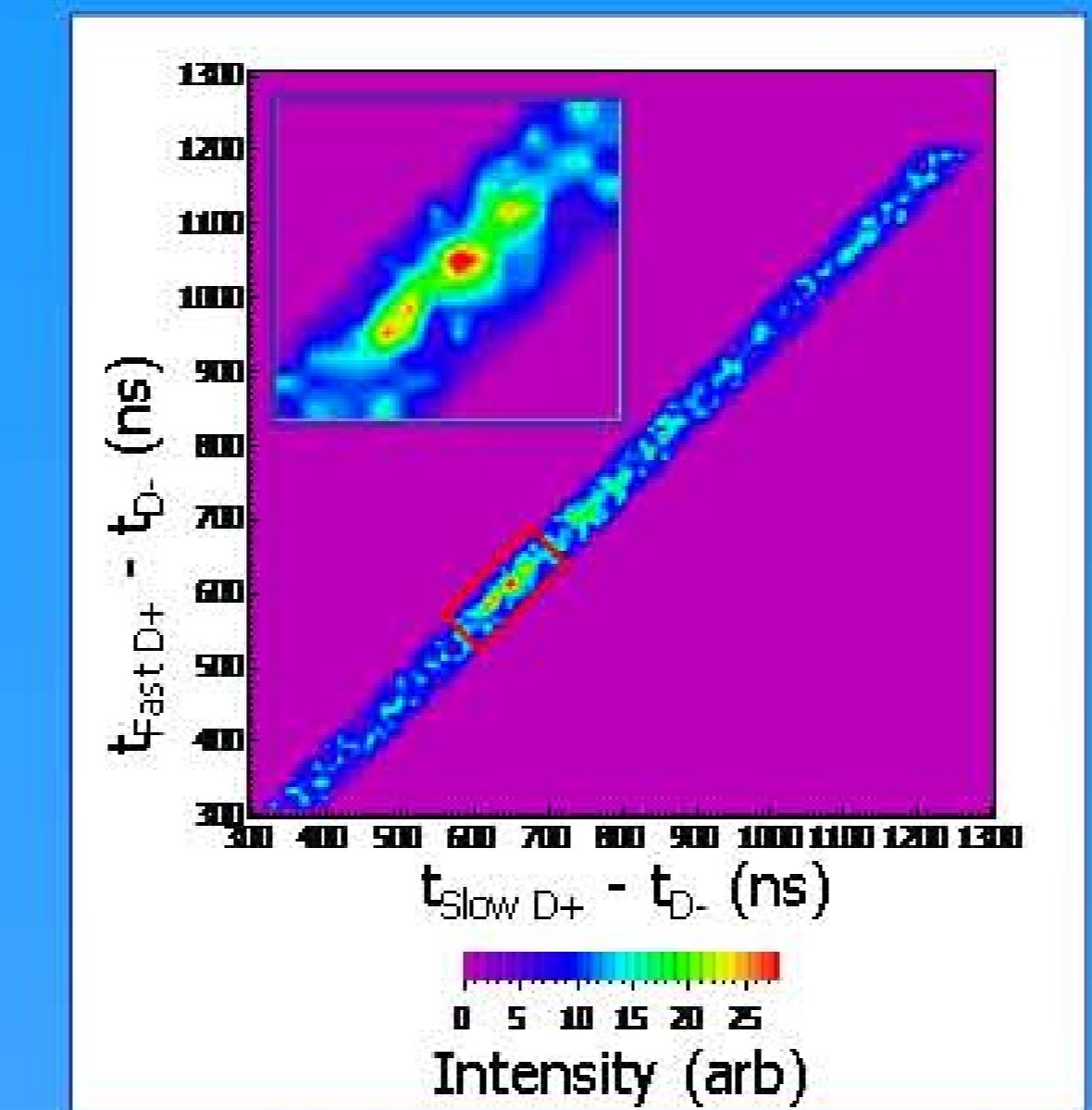


Figure 4. Time spectrum for accumulated data Abscissa is the detector arrival time difference between the Slow  $D^+$  and the  $D^-$ , and the ordinate is between the Fast  $D^+$  and  $D^-$ . Box and inset denotes peak-of-interest.

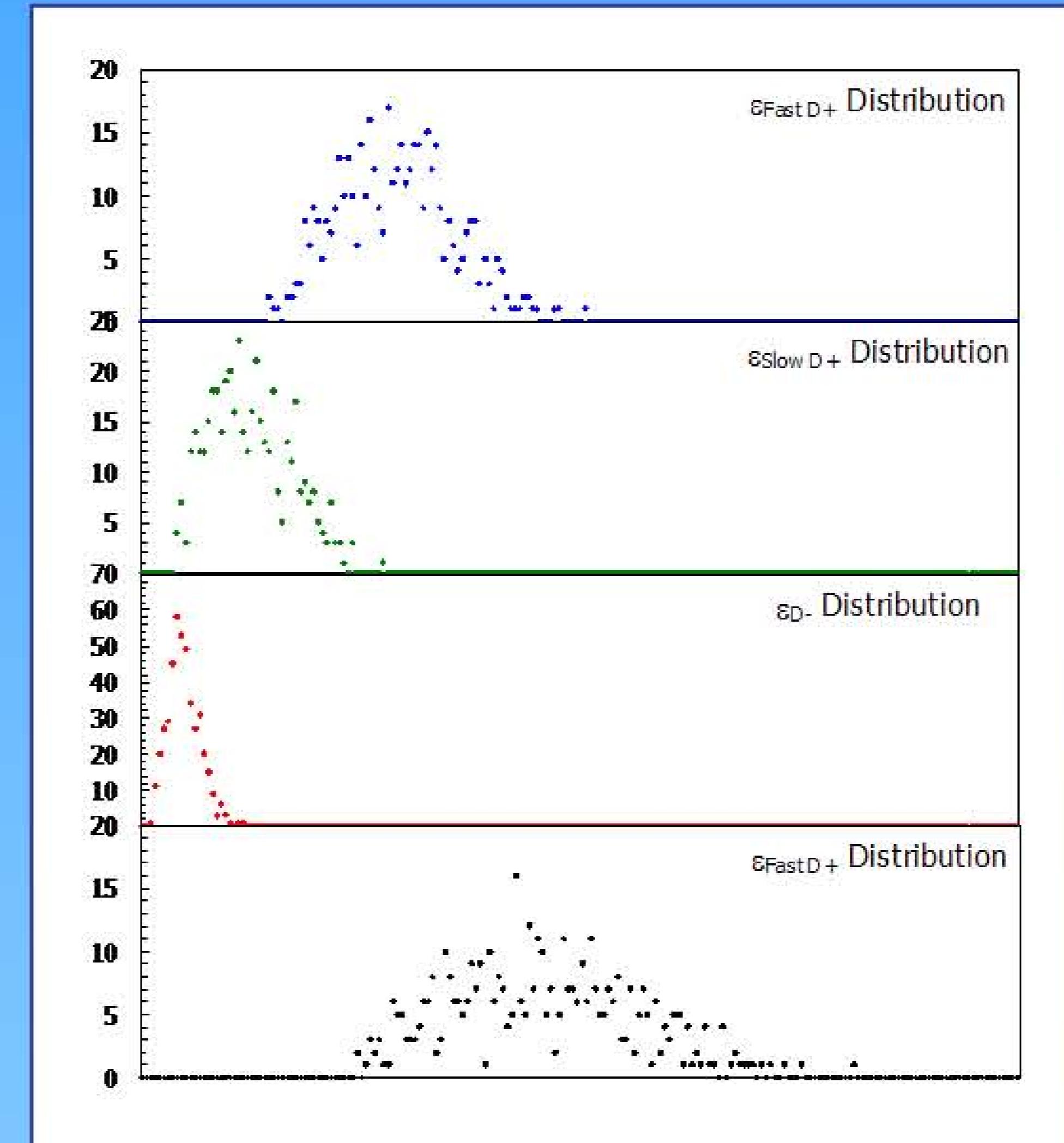


Figure 5. CM energy distributions from the filtered peak in Figure 4, totaling 308 events.

## Dalitz Plots

Dalitz Plot helps visualize three body correlations, as well as energy and momentum conservation.

- Fraction of particles cm energy is plotted as distance from triangle's side.
- Conservation of momentum lies inside inscribed circle.
- $\phi_{CA}$  decreases as vertical distance from base of triangle.
- Planetary atoms will form at P.

Figure 6. Introduction to Dalitz Plot.

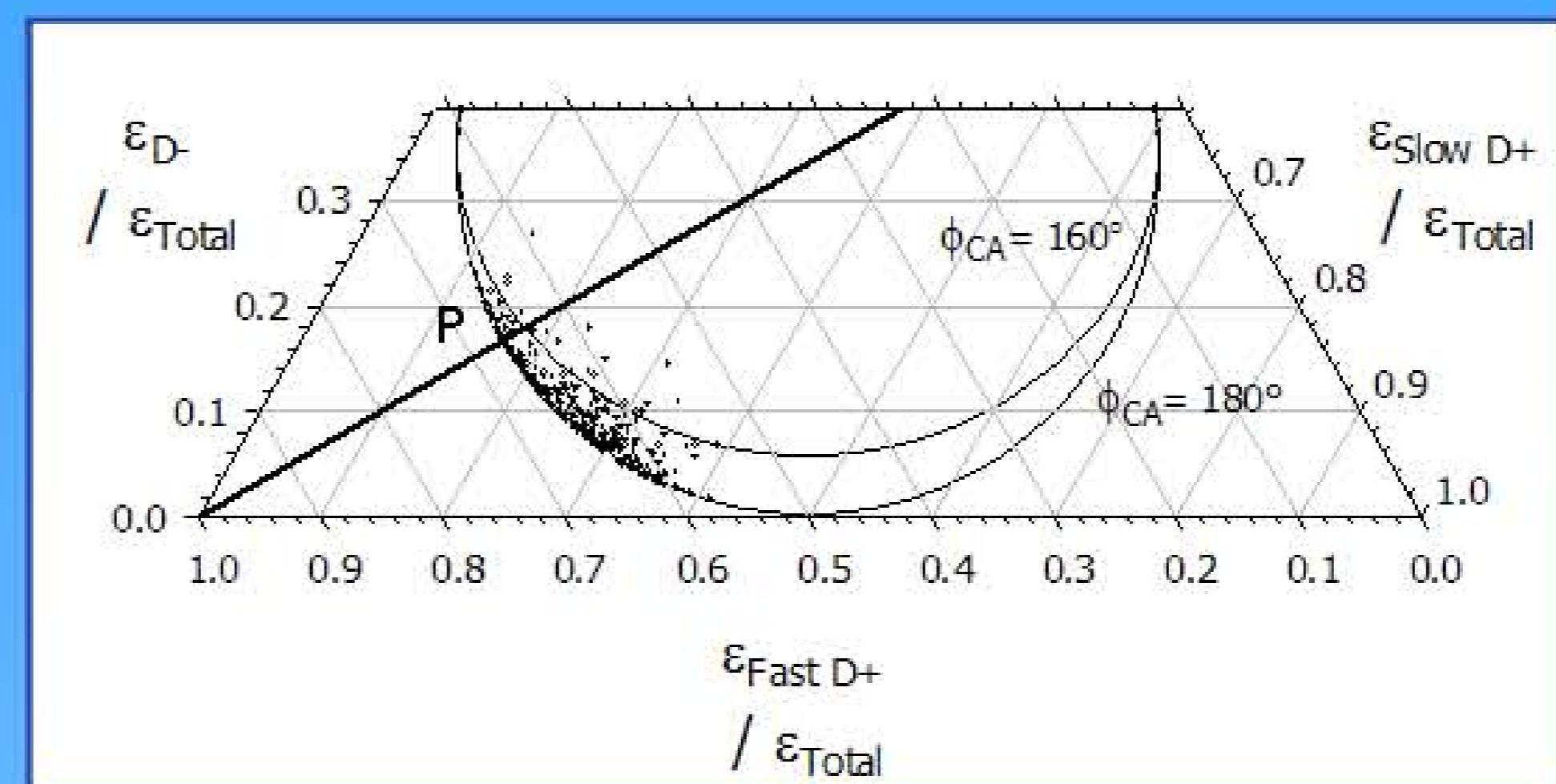


Figure 7. Dalitz plot of all events in peak of interest.

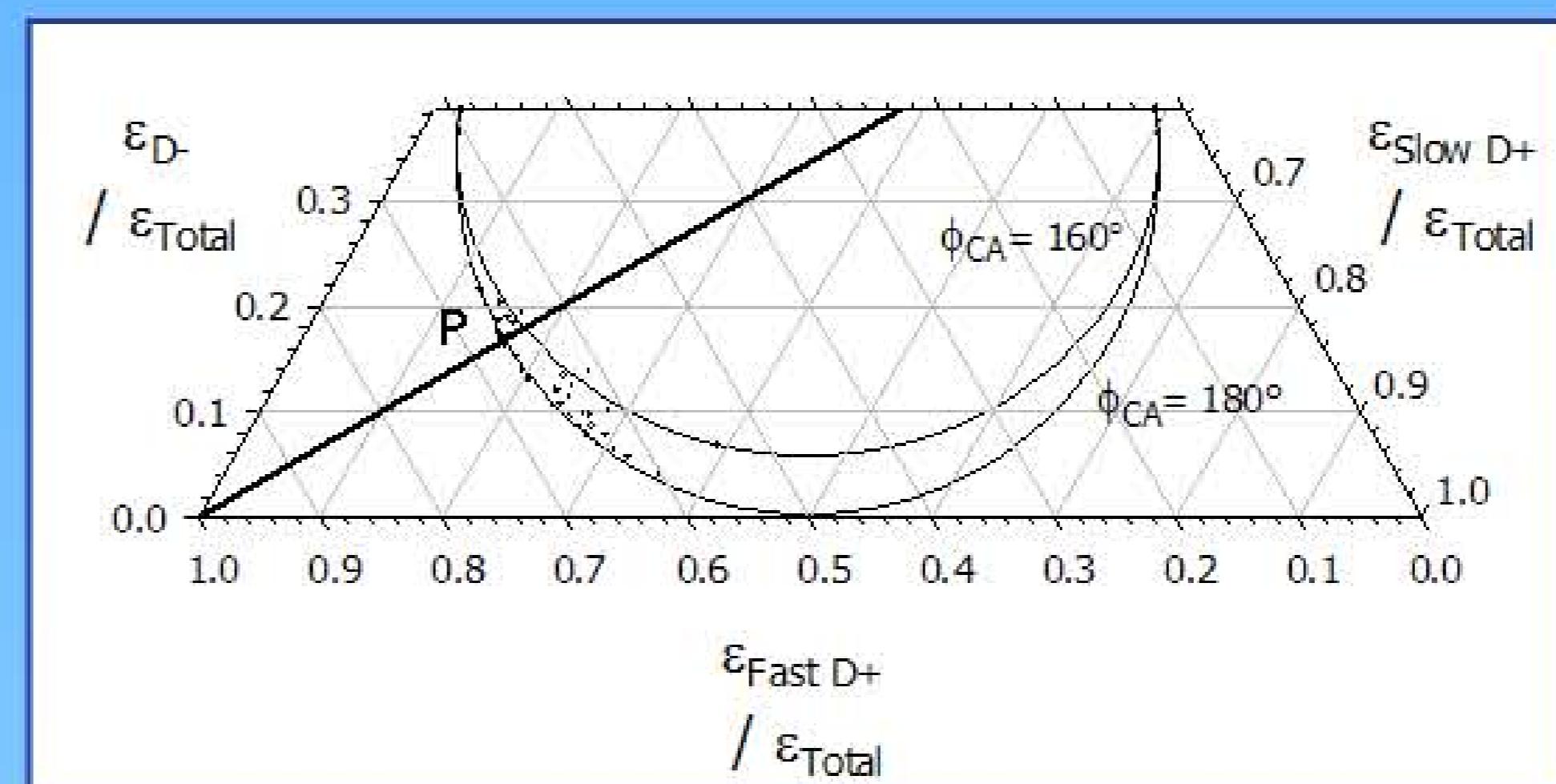


Figure 8. Dalitz plot of events with  $6 \text{ eV} < \epsilon_{Total} < 7 \text{ eV}$ .

## Dalitz Plots Continued

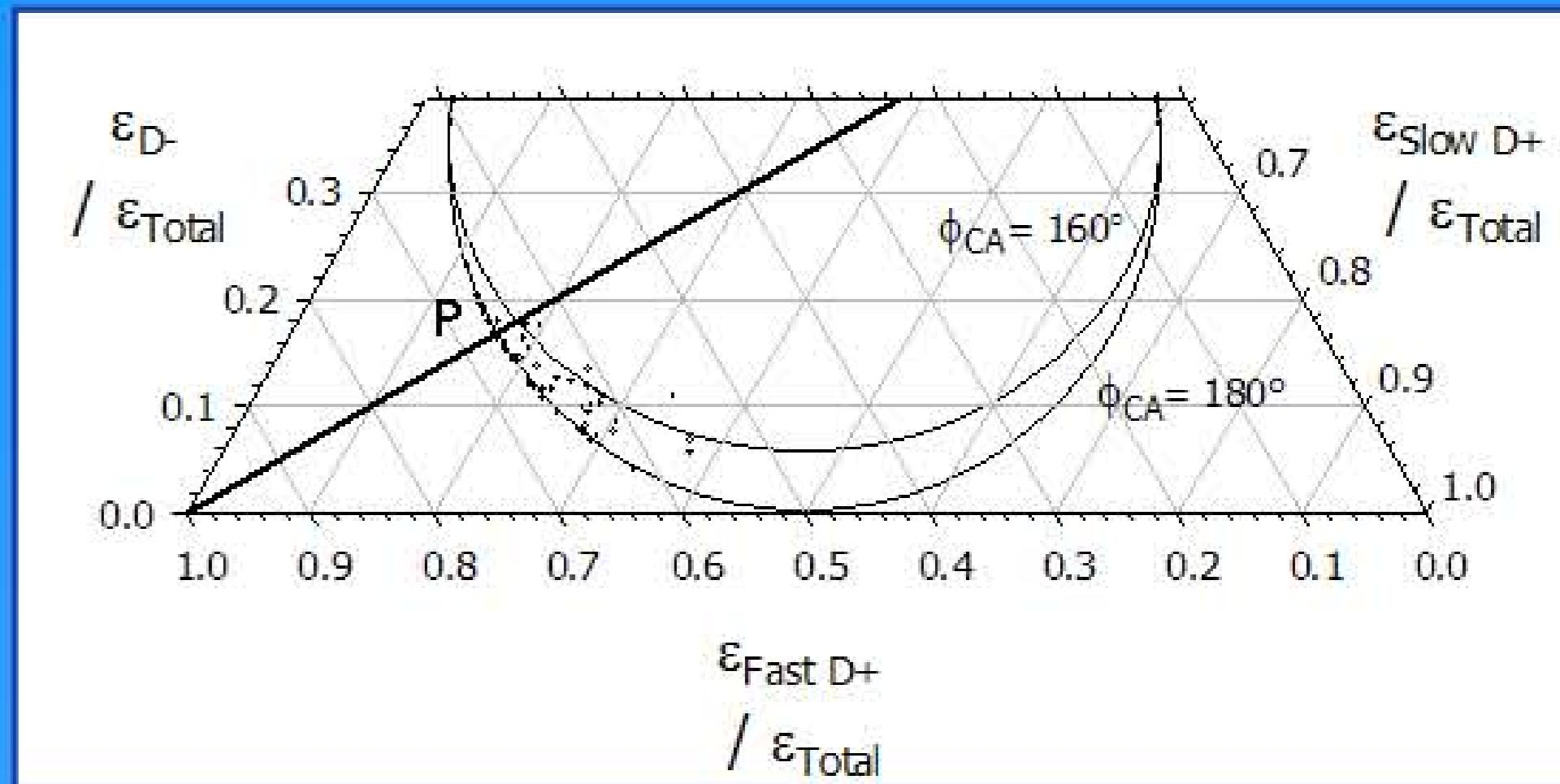


Figure 9. Dalitz plot of events with  $7 \text{ eV} < \epsilon_{Total} < 8 \text{ eV}$ .

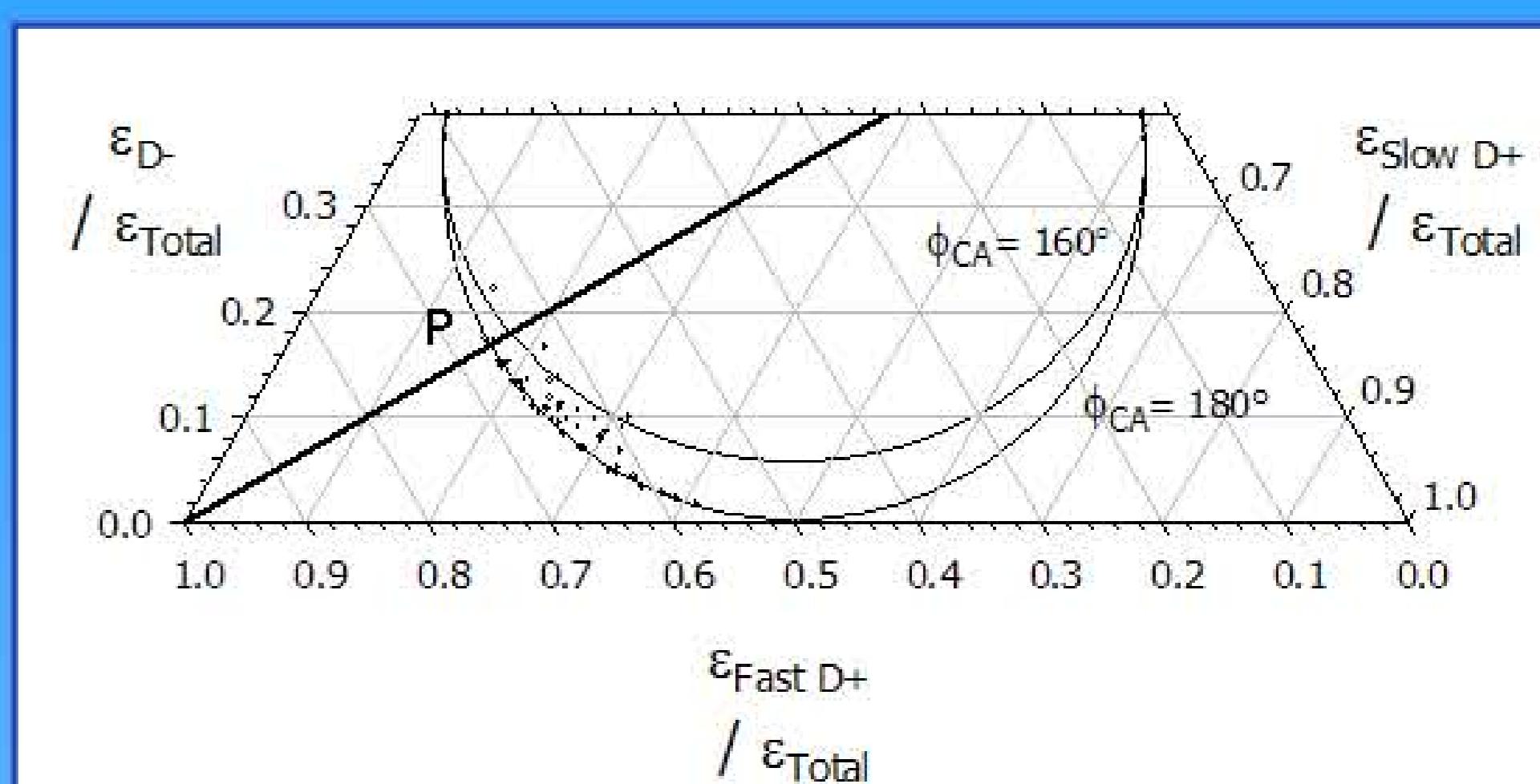


Figure 10. Dalitz plot of events with  $8 \text{ eV} < \epsilon_{Total} < 9 \text{ eV}$ .

## Mass Dependence

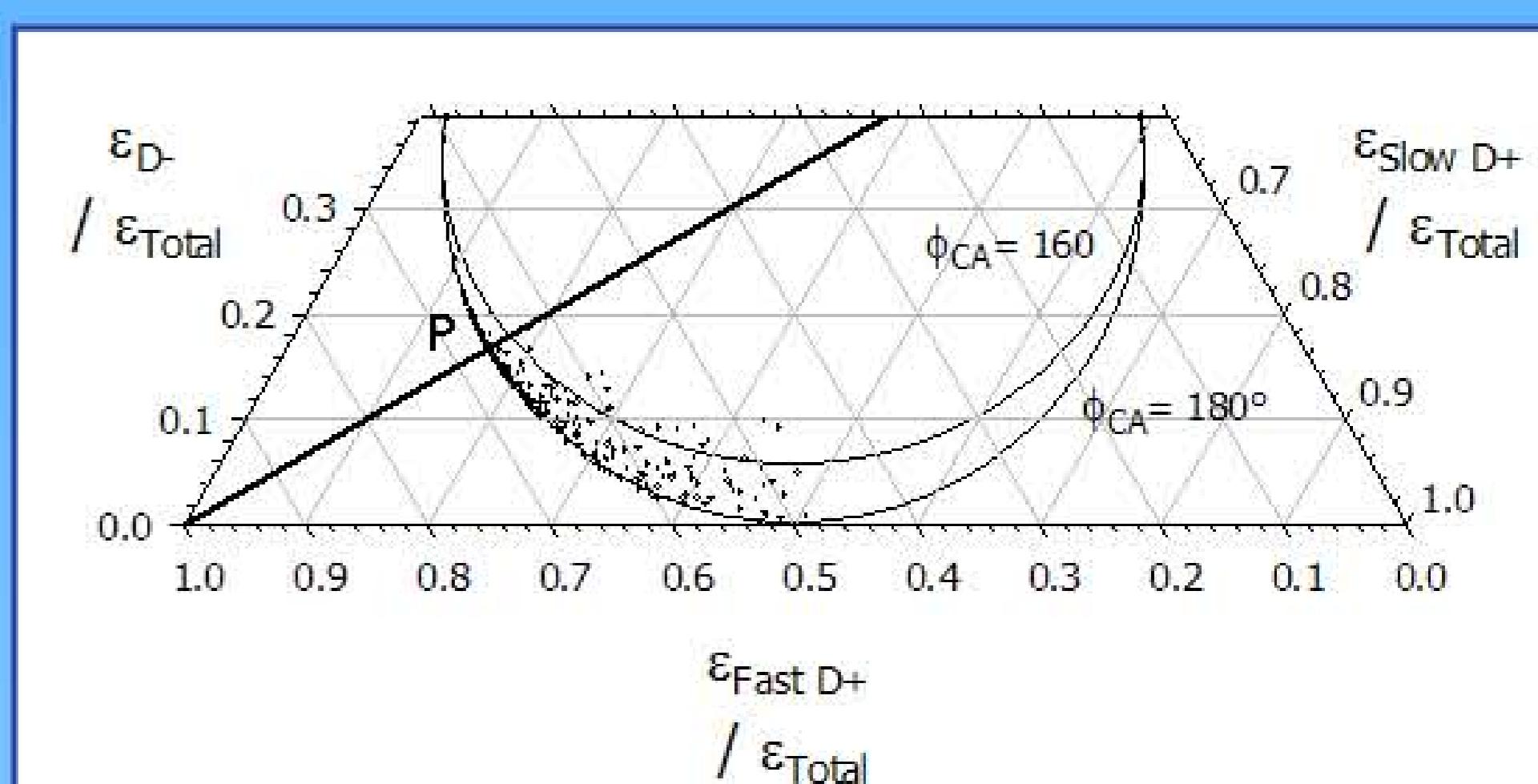


Figure 11. Dalitz plot for  $H_3^{+2}$ .

## Conclusions

We completely measure the cm energy and cm scattering angles for three particles interacting through the Coulomb potential.

We can also access the influence of  $\epsilon_{Total}$  on the final state dynamics of a three body system. From Figure 8, 9 and 10, the probability of forming a system with a  $D^+$  and  $D^-$  with equal energies decreases with increasing  $\epsilon_{Total}$ .

With a change of the parent molecular ion, we can determine the importance of mass in three body interactions. Comparing Figures 7 and 11, a more massive system increases the probability of forming a final state with  $\phi_{CA}$  less than  $180^\circ$ .

## References

- 1 L.M. Wiese, O. Yener, B. Thaden, M.Hiller, and D.H.Jaeck, Bulletin of the American Physical Society (1999) p. 1248
- 2 L.M. Wiese, O. Yener, B. Thaden, and D.H. Jaeck, Phys. Rev. Lett. **79**, 4982 (1997)

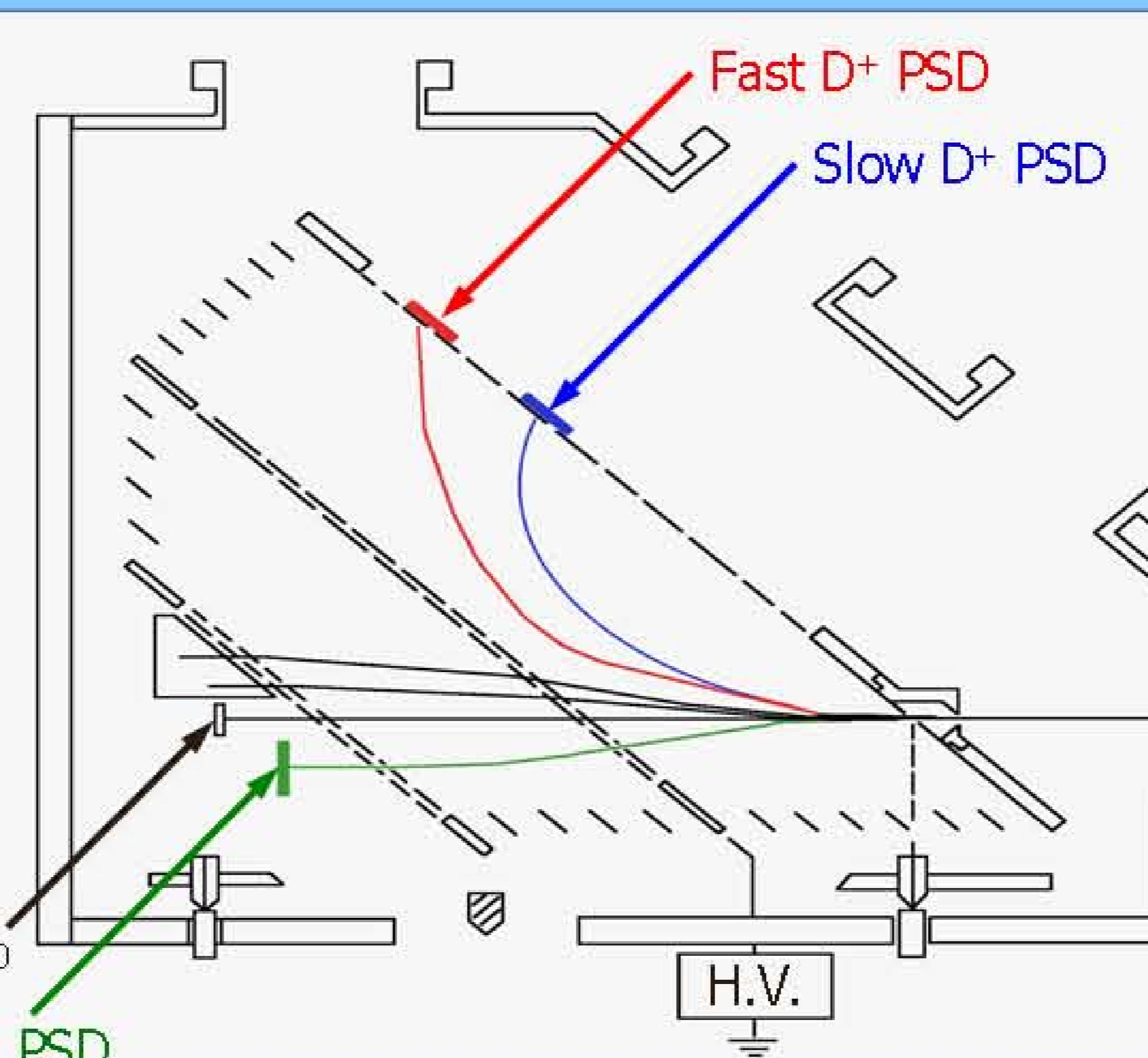


Figure 12. Experimental Apparatus